SEISMIC HAZARD ZONE REPORT FOR THE ROSAMOND 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

2005

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California Geological Survey

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EXECUTIVE SUMMARY

This report and the accompanying Preliminary Seismic Hazard Zones Map for the Los Angeles County portion of the Rosamond 7.5-Minute Quadrangle, California, are revisions of the original preliminary report and map that were released April 17, 2003. This report and map reflect required changes following the adoption of revised seismic hazard zone mapping criteria by the State Mining and Geology Board in April 2004. Accordingly, the 90-day period provided for public review is repeated, beginning on the release date noted on the revised Preliminary Seismic Hazard Zones map. The report summarizes the methods and sources of information used to prepare the accompanying seismic hazard zones map. The map displays the boundaries of zones of required investigation for liquefaction and earthquake-induced landslides over an area of approximately 62 square miles at a scale of 1 inch = 2,000 feet. No zones of required investigation for earthquake-induced landslides exist in the Los Angeles portion of the quadrangle. The northern half of the quadrangle in Kern County was not evaluated.

The Rosamond Quadrangle is in central Antelope Valley along the boundary between Los Angeles and Kern counties. The center of the area is about 10 miles north of Lancaster and 53 miles north of the Los Angeles Civic Center. The area is mostly nearly level high desert grassland and/or dry lakebed. The southern slopes of the Rosamond Hills in Kern County extend across the northern boundary and the community of Rosamond is also near the northern boundary. The land south of Avenue E and west of State Highway 14 (Antelope Valley Freeway) along the southern boundary of the quadrangle is within the City of Lancaster. A portion of the Air Force Flight Test Center (Edwards Air Force Base) is along the eastern boundary. The rest of the land is unincorporated. The highest point, above 2,500 feet, is in the Rosamond Hills on the northern boundary and the lowest point, below 2,290 feet, is on the eastern boundary. Access to the region is primarily via State Highway 14 (Antelope Valley Freeway) State Highway 138 (Avenue D) and a grid of east-west avenues (lettered) and north-south streets (numbered).

The map is prepared by employing geographic information system (GIS) technology, which allows the manipulation of three-dimensional data. Information considered includes topography, surface and subsurface geology, borehole data, historical ground-water levels, existing landslide features, slope gradient, rock-strength measurements, geologic structure, and probabilistic earthquake shaking estimates. The shaking inputs are based upon probabilistic seismic hazard maps that depict peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years.

The liquefaction zone covers an area along the eastern margin of the quadrangle where recent ground-water depths have been less than 40 feet, an area occupied by the wash of Amargosa Creek, and the large sewage treatment facility situated at State Route 14 and Avenue D.

How to view or obtain the map

Seismic Hazard Zone Maps, Seismic Hazard Zone Reports and additional information on seismic hazard zone mapping in California are available on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

Paper copies of Official Seismic Hazard Zone Maps, released by CGS, which depict zones of required investigation for liquefaction, are available for purchase from:

BPS Reprographic Services
945 Bryant Street
San Francisco, California 94103
(415) 512-6550

Seismic Hazard Zone Reports (SHZR) summarize the development of the hazard zone map for each area and contain background documentation for use by site investigators and local government reviewers. These reports are available for reference at CGS offices in Sacramento, San Francisco, and Los Angeles. **NOTE: The reports are not available through BPS Reprographic Services.**

INTRODUCTION

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate seismic hazard zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. They must withhold development permits for a site within a zone until the geologic and soil conditions of the project site are investigated and appropriate mitigation measures, if any, are incorporated into development plans. The Act also requires sellers (and their agents) of real property within a mapped hazard zone to disclose at the time of sale that the property lies within such a zone. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

The Act directs SMGB to appoint and consult with the Seismic Hazards Mapping Act Advisory Committee (SHMAAC) in developing criteria for the preparation of the seismic hazard zone maps. SHMAAC consists of geologists, seismologists, civil and structural engineers, representatives of city and county governments, the state insurance commissioner and the insurance industry. In 1991 SMGB adopted initial criteria for delineating seismic hazard zones to promote uniform and effective statewide implementation of the Act. These initial criteria, which were published in 1992 as CGS Special Publication 118, were revised in 1996 and 2004. The Act also directed CGS to develop a set of probabilistic seismic maps for California and to research methods that might be appropriate for mapping earthquake-induced landslide hazards.

In 1996, working groups established by SHMAAC reviewed the prototype maps and the techniques used to create them. The reviews resulted in recommendations that 1) the process for zoning liquefaction hazards remain unchanged and 2) earthquake-induced landslide zones be delineated using a modified Newmark analysis.

In April 2004, significant revisions of liquefaction zone mapping criteria relating to application of historically high ground-water level data in desert regions of the state were adopted by the SMGB. These modifications are reflected in the revised CGS Special Publication 118 (DOC, 2004), which is available on the Internet at: http://gmw.consrv.ca.gov/shmp/webdocs/sp118_revised.pdf

This report and the accompanying Preliminary Seismic Hazard Zones map incorporate the newly adopted criteria and replace the original preliminary report and map that were released in April 17, 2003. The report summarizes the development of the hazard zone map. The process of zoning for liquefaction uses a combination of Quaternary geologic mapping, ground-water information, and subsurface geotechnical data. The process for zoning earthquake-induced landslides incorporates earthquake loading, existing landslide features, slope gradient, rock strength, and geologic structure. Probabilistic seismic hazard maps, which are the underpinning for delineating seismic hazard zones, have been prepared for peak ground acceleration, mode magnitude, and mode distance with a 10 percent probability of exceedance in 50 years (Petersen and others, 1996) in accordance with the mapping criteria.

This report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Rosamond 7.5-Minute Quadrangle.

SECTION 1
LIQUEFACTION EVALUATION REPORT

Liquefaction Zones in the Los Angeles County Part of the Rosamond 7.5-Minute Quadrangle, California

By
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Note: In April 2004, significant revisions of liquefaction zone mapping criteria relating to application of historically high ground-water levels in desert regions of the state were adopted by the State Mining and Geology Board (SMGB). These changes are reflected in the revised CGS Special Publication 118 (DOC, 2004), which is available on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp118_revised.pdf

This report and the accompanying Preliminary Seismic Hazard Zones Map for the Los Angeles County portion of the Rosamond Quadrangle, which are revisions of the original preliminary report and map released in April 17, 2003, incorporate the newly adopted zone mapping criteria.

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use seismic hazard zone maps developed by CGS in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within seismic hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines adopted by the California State Mining and Geology Board (SMGB) (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

Following the release of DMG Special Publication 117 (DOC, 1997), agencies in the Los Angeles metropolitan region sought more definitive guidance in the review of geotechnical investigations addressing liquefaction hazards. The agencies made their request through the Geotechnical Engineering Group of the Los Angeles Section of the American Society of Civil Engineers (ASCE). This group convened an implementation committee under the auspices of the Southern California Earthquake Center (SCEC). The committee, which consisted of practicing geotechnical engineers and engineering geologists, released an overview of the practice of liquefaction analysis, evaluation, and mitigation techniques (SCEC, 1999). This text is also on the Internet at: http://www.scec.org/

This section of the evaluation report summarizes seismic hazard zone mapping for potentially liquefiable soils in the Los Angeles County part of the Rosamond 7.5-Minute Quadrangle. The section and the accompanying Preliminary Seismic Hazard Zones map are revisions of an earlier preliminary report and map released April 17, 2003. The changes, which affect liquefaction zonation in some high desert regions, were prompted by SMGB adoption of revised criteria in April 2004 (DOC, 2004).

Section 3 (addressing potential ground shaking) completes the report, which is one of a series that summarizes production of similar seismic hazard zone maps within the state (Smith, 1996). Additional information on seismic hazards zone mapping in California is on CGS's Internet web page: http://www.consrv.ca.gov/CGS/index.htm

BACKGROUND

Liquefaction-induced ground failure historically has been a major cause of earthquake damage in southern California. During the 1971 San Fernando and 1994 Northridge earthquakes significant damage to roads, utility pipelines, buildings, and other structures in the Los Angeles area was caused by liquefaction-induced ground displacement.

Localities most susceptible to liquefaction-induced damage are underlain by loose, water-saturated, granular sediment within 40 feet of the ground surface. These geological and ground-water conditions exist in parts of southern, most notably in some densely populated valley regions and alluviated floodplains. In addition, the potential for strong earthquake ground shaking is high because of the many nearby active faults. The combination of these factors constitutes a significant seismic hazard in the southern California region in, including areas in the Rosamond Quadrangle.

METHODS SUMMARY

Characterization of liquefaction hazard presented in this report requires preparation of maps that delineate areas underlain by potentially liquefiable sediment. The following were collected or generated for this evaluation:

- Existing geologic maps were used to provide an accurate representation of the spatial distribution of Quaternary deposits in the study area. Geologic units that generally are susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill

- Shallow ground-water maps were constructed

- Geotechnical data were quantitatively analyzed to evaluate liquefaction potential of deposits

- Information on potential ground shaking intensity based on CGS probabilistic shaking maps

The data collected for this evaluation were processed into a series of geographic information system (GIS) layers using commercially available software. The liquefaction zone map was derived from a synthesis of these data and according to criteria adopted by the SMGB (DOC, 2004).

SCOPE AND LIMITATIONS

Evaluation for potentially liquefiable soils generally is confined to areas covered by Quaternary (less than about 1.6 million years) sedimentary deposits. Such areas within the Rosamond Quadrangle consist mainly of the alluviated valley floor. CGS's liquefaction hazard evaluations are based on information on earthquake ground shaking, surface and subsurface lithology, geotechnical soil properties, and ground-water depth, which is gathered from various sources. Although selection of data used in this evaluation was rigorous, the quality of the data used varies. The State of California and the Department of Conservation make no representations or warranties regarding the accuracy of the data obtained from outside sources.

Liquefaction zone maps are intended to prompt more detailed, site-specific geotechnical investigations, as required by the Act. As such, liquefaction zone maps identify areas where the potential for liquefaction is relatively high. They do not predict the amount or direction of liquefaction-related ground displacements, or the amount of damage to facilities that may result from liquefaction. Factors that control liquefaction-induced ground failure are the extent, depth, density, and thickness of liquefiable materials, depth to ground water, rate of drainage, slope gradient, proximity to free faces, and intensity and duration of ground shaking. These factors must be evaluated on a site-specific basis to assess the potential for ground failure at any given project site.

Information developed in the study is presented in two parts: physiographic, geologic, and hydrologic conditions in PART I, and liquefaction and zoning evaluations in PART II.

PART I

PHYSIOGRAPHY

Study Area Location and Physiography

The Rosamond 7.5-Minute Quadrangle covers approximately 62 square miles in central Antelope Valley along the boundary between Los Angeles and Kern counties. Only 34 square miles in the southern, Los Angeles County, portion of the quadrangle was evaluated for zoning. The center of the area is about 10 miles north of Lancaster and 53 miles north of the Los Angeles Civic Center. Topographically, the area is mostly nearly level high desert grassland and/or dry lakebed. The southern slopes of the Rosamond Hills in Kern County extend across the northern boundary and the community of Rosamond is also near the northern boundary.

The land south of Avenue E and west of State Highway 14 (Antelope Valley Freeway) along the southern boundary of the quadrangle is within the City of Lancaster. A portion of the Air Force Flight Test Center (Edwards Air Force Base) is along the eastern boundary. The rest of the land is unincorporated. Sewage treatment ponds and duck ponds are scattered in various places within the quadrangle. The highest point in the quadrangle, above 2,500 feet, is in the Rosamond Hills on the northern boundary. The lowest point, below 2,290 feet, is on the eastern boundary. Access to the region is primarily via State Highway 14 (Antelope Valley Freeway) State Highway 138 (Avenue D) and a grid of east-west avenues (lettered) and north-south streets (numbered).

GEOLOGY

Bedrock and Surficial Geology

Geologic units that are generally susceptible to liquefaction include late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. For this evaluation, the Quaternary geologic map of Antelope Valley (Ponti, 1980; Ponti and others, 1981) was digitized by the Southern California Areal Mapping Project. The geology for the evaluated part of the Rosamond Quadrangle was extracted from this regional map, with minor modifications added by CGS to form a 1:24,000-scale map. Plate 1.1 shows the generalized Quaternary geology of the Rosamond Quadrangle that was used in combination with other data to evaluate liquefaction potential and develop the Seismic Hazard Zone Map.

Quaternary alluvial deposits cover the entire Los Angeles County portion of the Rosamond Quadrangle. These Pleistocene through Holocene surficial deposits are summarized in Table 1.1. Ponti and others (1981) mapped the Quaternary units based on relative age (Q1-7; 1 being oldest) and grain size (f=fine, m=medium, and c=coarse). Deposits exposed in the area evaluated are described below.

Covering just over a square mile in the southwestern corner of the quadrangle is a medium-grained sedimentary unit (Quca) rich in secondary calcium carbonate. Ponti and others (1981) assume the parent materials to be equivalent to Q4, Q5, and Q6 alluvial deposits of late Pleistocene to Holocene (see description below). Within the area evaluated these deposits are most likely equivalent to sediments mapped as Q6. The unit, which locally contains up to 50 percent calcium carbonate concretions and platy cemented layers, is considered by Ponti (1980) to have been affected by fluctuating ground water during late Pleistocene and early Holocene time. In the Rosamond Quadrangle, the presence of calcium carbonate is usually limited to a zone extending to depths between 5 and 15 feet.

Sediments mapped by Ponti and others (1981) as Quaternary playa deposits (Qpl) cover most of the evaluated part of the quadrangle. Regionally, these sediments are described as compact lacustrine silt and clay with minor loose, well-sorted sand and fine gravel deposited in the shallow-water margins of the last pluvial lake that filled the lowland parts of Antelope Valley up to about 12,000 years ago. However, deposits mapped Qpl in the Rosamond Quadrangle appear to contain significant amounts of loose sand and silt in the top 40 feet of the stratigraphic section (see Engineering Geology section).

Map Unit	Environment of Deposition	Age
Q7	alluvial fan	latest Holocene
Q6	alluvial fan, wash, colluvial aprons	late Pleistocene and Holocene
Quca	alluvial fan, with secondary carbonate	late Pleistocene and Holocene
Qpl	playa deposits	late Pleistocene and Holocene

Table 1.1. Map Units Used in the Rosamond Quadrangle (after Ponti and others, 1981).

Holocene alluvial fan and wash sediments (Q6) are unconsolidated, mainly medium-grained sediments representing deposition during latest Pleistocene and Holocene time. Soils on these alluvial fan and colluvial materials are weakly developed. These deposits represent the youngest sediments deposited on the alluvial fan approaching the quadrangle from the west and within and adjacent to Amargosa Creek.

Latest Holocene coarse- to medium-grained clastic sediments (Q7) are mapped within parts of Amargosa Creek. These deposits are unconsolidated with little, if any, soil development.

Structural Geology

The Rosamond Quadrangle occupies a portion of the Antelope Valley, a wedge-shaped part of the Mojave Desert bounded on the northwest by the Garlock Fault and the Tehachapi Mountains, and on the south by the San Andreas Fault and the Transverse Ranges. The San Andreas Fault Zone is approximately 10 miles south of the area evaluated, whereas the Garlock Fault lies about 23 miles to the north. Evidence of Holocene surface faulting has not been found within the project area.

ENGINEERING GEOLOGY

As stated above, soils that are generally susceptible to liquefaction are mainly late Quaternary alluvial and fluvial sedimentary deposits and artificial fill. Deposits that contain saturated loose sandy and silty soils are most susceptible to liquefaction. Lithologic descriptions and soil test results reported in geotechnical borehole logs provide valuable information regarding subsurface geology, ground-water levels, and the engineering characteristics of sedimentary deposits.

Of particular value in liquefaction evaluations are logs that report the results of down-hole standard penetration tests. Standard Penetration Tests (SPTs) provide a uniform measure of the penetration resistance of geologic deposits and are commonly used as an index of soil density. This in-field test consists of counting the number of blows required to drive a split-spoon sampler (1.375-inch inside diameter) one foot into the soil at the bottom of a borehole at chosen intervals while drilling. The driving force is provided by dropping a 140-pound hammer weight 30 inches. The SPT method is formally defined and specified by the American Society for Testing and Materials (2004) in test method D1586. Recorded blow counts for non-SPT geotechnical sampling where the sampler diameter, hammer weight or drop distance differ from those specified for an SPT (ASTM D1586), are converted to SPT-equivalent blow counts. The actual and converted SPT blow counts are normalized to a common-reference, effective-overburden pressure of one atmosphere (approximately one ton per square foot) and a hammer efficiency of 60 percent using a method described by Seed and Idriss (1982) and Seed and others (1985). This normalized blow count is referred to as $(N_1)_{60}$.

The Seed-Idriss Simplified Procedure for liquefaction evaluation was developed primarily for clean sand and silty sand. As described above, results depend greatly on accurate evaluation of in-situ soil density as measured by the number of soil penetration blow counts using an SPT sampler. However, many of the Holocene alluvial deposits in the study area contain a significant amount of gravel. In the past, gravelly soils were considered not to be susceptible to liquefaction because the high permeability of these soils presumably would allow the dissipation of pore pressures before liquefaction could occur. However, liquefaction in gravelly soils has been observed during earthquakes, and recent laboratory studies have shown that gravelly soils are susceptible to liquefaction (Ishihara, 1985; Harder and Seed, 1986; Budiman and Mohammadi, 1995; Evans and Zhou, 1995; and Sy and others, 1995). SPT-derived density measurements in gravelly soils are unreliable and generally too high. They are likely to lead to overestimation of the density of the soil and, therefore, result in an underestimation of the liquefaction susceptibility. To identify potentially liquefiable units where the N values appear to have been affected by gravel content, correlations were made with boreholes in the same unit where the N values do not appear to have been affected by gravel content.

During the initial stages of this investigation, CGS obtained logs of geotechnical boreholes that had been drilled in various localities within Antelope Valley. Staff collected the logs from the files of the cities of Lancaster and Palmdale, California Department of Transportation, Los Angeles County Public Works Department, and Earth Systems, Inc. Nine of the logs are from boreholes drilled within the Rosamond Quadrangle. The drill sites were digitally located and associated log data entered into the CGS geotechnical GIS database to enable computer-assisted liquefaction analysis and evaluation. In addition, the data provided in geotechnical borehole logs were augmented by examination of lithologic descriptions included in the logs of scores of water wells drilled in the study area.

Examination of borehole and water-well logs indicate that throughout the Rosamond Quadrangle sedimentary deposits at depths of less than 40 feet are composed predominantly of loose to dense sandy and silty sediments, even within the area mapped by Ponti and others (1981) as lacustrine playa deposits (see Geology section).

Geologic Map Unit	Material Type	Consistency	Age	Liquefaction Susceptibility*
overbank (Q7)	sand, gravel, & silt	loose	Holocene & late Pleistocene	high
alluvial fan, overbank, sheet flood (Q6)	sand, gravel, & silt	loose to dense	Holocene & late Pleistocene	high to moderate
alluvial fan w/ secondary carbonate (Quca)	sand and silt w/ up to 10-foot thick zone of calcium carbonate cement	loose to very dense	Holocene & late Pleistocene	high to low
playa deposits (Qpl)	sand, silt, clay	loose to dense	Holocene & late Pleistocene	high to low

*when saturated

Table 1.2. Quaternary Map Units Used in the Rosamond 7.5-Minute Quadrangle and Their Geotechnical Characteristics and Liquefaction Susceptibility

GROUND WATER

Saturation reduces the effective normal stress of near-surface sediment, thereby increasing the likelihood of earthquake-induced liquefaction (Youd, 1973). CGS compiles and interprets ground-water data to identify areas characterized by, or anticipated to have in the future, near-surface saturated soils. For purposes of seismic hazard zonation, "near-surface" means at a depth less than 40 feet.

Natural hydrologic processes and human activities can cause ground-water levels to fluctuate over time. Therefore, it is impossible to predict depths to saturated soils during future earthquakes. One method of addressing time-variable depths to saturated soils is to establish an anticipated high ground-water level based on historical ground-water data. In areas where ground water is either currently near-surface or could return to near-surface within a land-use planning interval of 50 years, CGS constructs regional contour maps that depict these levels. In some areas with low precipitation, such as Antelope Valley, records may indicate that near-surface ground water existed during historical time, but large withdrawal and low recharge rates preclude a return to those conditions within 50 years. For these areas, the historically highest ground-water level is not used to establish the anticipated depth to saturated soil used for hazard evaluation. For these and all other areas, CGS delineates present or anticipated near-surface saturated soils caused by locally perched water and seepage from surface-water bodies.

Future initiation of large-scale, artificial recharge programs could result in significant rises in ground-water levels over 50 years. When alerted of such plans, CGS will evaluate their impacts relative to liquefaction potential and revise official seismic hazard zone maps, if necessary. Plate 1.2 depicts areas characterized by present or anticipated shallow ground water within the Rosamond Quadrangle. The levels are based mainly on a ground-water basin study of Antelope Valley conducted by Carlson and others (1998) that show regional ground-water levels less than 40 feet deep occur along the eastern margin of the quadrangle in the vicinity of Rosamond Lake. Shallow ground water is also expected to occur within and immediately adjacent to the large sewage treatment facility at State Route 14 and Avenue D.

Boreholes drilled by the California Department of Transportation (CalTrans) along State Route 14 between Avenues D and G in the late 1960's early 1970's report ground water at depths less than 40 feet, the shallowest being at a depth of 12 feet at Avenue E (the site of a pre-existing artificial pond). However, local levels appear to have dropped dramatically during the last 30 years as indicated by regional ground-water levels presented in Carlson and others (1998). The drop in water levels is also demonstrated by a first-encountered ground-water depth of 80 feet reported in the log of a water well drilled at the mobile home park at Avenue E and Hwy 14 in 1999. Consequently, the CalTrans logged ground-water levels were not used in the evaluation.

Staff also used the following publications and internet sources to evaluate ground-water conditions and historical ground-water use in the Lancaster West and surrounding quadrangles: Johnson (1911); Thompson (1929); California Department of Water Resources (1965); Bloyd (1967); Durbin (1978); Duell (1987); Leighton and Associates

(1990); Templin and others (1995); Galloway and others (1998); Carlson and Phillips (1998); Sneed and Galloway (2000); Los Angeles County Department of Public Works (2003); and California Department of Water Resources (2003). A detailed report of the ground-water hydrology of Antelope Valley is available on the U.S. Geological Survey web site (U.S. Geological Survey, 2003). In addition, satellite imagery provided by ASTER (2001) was used to identify and delineate major drainages and surface water bodies.

PART II

LIQUEFACTION POTENTIAL

Liquefaction may occur in water-saturated sediment during moderate to great earthquakes. Liquefied sediment loses strength and may fail, causing damage to buildings, bridges, and other structures. Many methods for mapping liquefaction hazard have been proposed. Youd (1991) highlights the principal developments and notes some of the widely used criteria. Youd and Perkins (1978) demonstrate the use of geologic criteria as a qualitative characterization of liquefaction susceptibility and introduce the mapping technique of combining a liquefaction susceptibility map and a liquefaction opportunity map to produce a liquefaction potential map. Liquefaction susceptibility is a function of the capacity of sediment to resist liquefaction. Liquefaction opportunity is a function of the potential seismic ground shaking intensity.

The method applied in this study for evaluating liquefaction potential is similar to that of Tinsley and others (1985). Tinsley and others (1985) applied a combination of the techniques used by Seed and others (1983) and Youd and Perkins (1978) for their mapping of liquefaction hazards in the Los Angeles region. CGS's method combines geotechnical analyses, geologic and hydrologic mapping, and probabilistic earthquake shaking estimates, but follows criteria adopted by the SMGB (DOC, 2004).

LIQUEFACTION SUSCEPTIBILITY

Liquefaction susceptibility reflects the relative resistance of a soil to loss of strength when subjected to ground shaking. Physical properties of soil such as sediment grain-size distribution, compaction, cementation, saturation, and depth govern the degree of resistance to liquefaction. Some of these properties can be correlated to a sediment's geologic age and environment of deposition. With increasing age, relative density may increase through cementation of the particles or compaction caused by the weight of the overlying sediment. Grain-size characteristics of a soil also influence susceptibility to liquefaction. Sand is more susceptible than silt or gravel, although silt of low plasticity is treated as liquefiable in this investigation. Cohesive soils generally are not considered susceptible to liquefaction. Such soils may be vulnerable to strength loss with remolding and represent a hazard that is not addressed in this investigation. Soil characteristics and processes that result in higher measured penetration resistances generally indicate lower liquefaction susceptibility. Thus, blow count and cone penetrometer values are useful indicators of liquefaction susceptibility.

Saturation is required for liquefaction, and the liquefaction susceptibility of a soil varies with the depth to ground water. Very shallow ground water increases the susceptibility to liquefaction (soil is more likely to liquefy). Soils that lack resistance (susceptible soils) typically are saturated, loose and sandy. Soils resistant to liquefaction include all soil types that are dry, cohesive, or sufficiently dense.

CGS's map inventory of areas containing soils susceptible to liquefaction begins with evaluation of geologic maps and historical occurrences, cross-sections, geotechnical test data, geomorphology, and ground-water hydrology. Soil properties and soil conditions such as type, age, texture, color, and consistency, along with historical depths to ground water are used to identify, characterize, and correlate susceptible soils. Because Quaternary geologic mapping is based on similar soil observations, liquefaction susceptibility maps typically are similar to Quaternary geologic maps

LIQUEFACTION OPPORTUNITY

Liquefaction opportunity is a measure, expressed in probabilistic terms, of the potential for strong ground shaking. Analyses of in-situ liquefaction resistance require assessment of liquefaction opportunity. The minimum level of seismic excitation to be used for such purposes is the level of peak ground acceleration (PGA) with a 10 percent probability of exceedance over a 50-year period (DOC, 2004). The earthquake magnitude used in CGS's analysis is the magnitude that contributes most to the calculated PGA for an area.

For the Rosamond Quadrangle, PGAs ranging from 0.35 to 046g, resulting from a predominant earthquake of magnitude 7.8, were used for liquefaction analyses. The PGA and magnitude values were based on de-aggregation of the probabilistic hazard at the 10 percent in 50-year hazard level (Petersen and others, 1996; Cramer and Petersen, 1996). See the ground motion portion (Section 3 of this report for further details.

Quantitative Liquefaction Analysis

CGS performs quantitative analysis of geotechnical data to evaluate liquefaction potential using the Seed-Idriss Simplified Procedure (Seed and Idriss, 1971; Seed and others, 1983; National Research Council, 1985; Seed and others, 1985; Seed and Harder, 1990; Youd and Idriss, 1997; Youd and others, 2001). Using the Seed-Idriss Simplified Procedure one can calculate soil resistance to liquefaction, expressed in terms of cyclic resistance ratio (CRR), based on SPT results, ground-water level, soil density, moisture content, soil type, and sample depth. CRR values are then compared to calculated earthquake-generated shear stresses expressed in terms of cyclic stress ratio (CSR). The Seed-Idriss Simplified Procedure requires normalizing earthquake loading relative to a M7.5 event for the liquefaction analysis. To accomplish this, CGS's analysis uses the Idriss magnitude-scaling factor (MSF) (Youd and Idriss, 1997). It is convenient to think in terms of a factor of safety (FS) relative to liquefaction, where: $FS = (CRR / CSR) * MSF$. FS, therefore, is a quantitative measure of liquefaction potential. CGS uses a factor of safety of 1.0 or less, where CSR equals or exceeds CRR, to indicate the presence of potentially liquefiable soil. While an FS of 1.0 is considered the "trigger" for liquefaction, for a site specific analysis an FS of as much as 1.5 may be appropriate depending on the vulnerability of the site and related structures.

The CGS liquefaction analysis program calculates an FS for each geotechnical sample where blow counts were collected. Typically, multiple samples are collected for each borehole. The program then independently calculates an FS for each non-clay layer that includes at least one penetration test using the minimum $(N_1)_{60}$ value for that layer. The minimum FS value of the layers penetrated by the borehole is used to determine the liquefaction potential for each borehole location. The reliability of FS values varies according to the quality of the geotechnical data. FS, as well as other considerations such as slope, presence of free faces, and thickness and depth of potentially liquefiable soil, are evaluated in order to construct liquefaction potential maps, which are then used to make a map showing zones of required investigation.

Most of the 9 geotechnical borehole logs reviewed in this study (Plate 1.2) include blow-count data from SPTs or from penetration tests that allow reasonable blow count translations to SPT-equivalent values. Non-SPT values, such as those resulting from the use of 2-inch or 2½-inch inside-diameter ring samplers, are generally translated to SPT-equivalent values if reasonable factors can be used in conversion calculations. The reliability of the SPT-equivalent values varies. Therefore, they are weighted and used in a more qualitative manner. Few borehole logs, however, include all of the information (e.g. soil density, moisture content, sieve analysis, etc.) required for an ideal Seed-Idriss Simplified Procedure. For boreholes having acceptable penetration tests, liquefaction analysis is performed using recorded density, moisture, and sieve test values or using averaged test values of similar materials.

LIQUEFACTION ZONES

Criteria for Zoning

Areas underlain by materials susceptible to liquefaction during an earthquake were included in liquefaction zones using criteria developed by the Seismic Hazards Mapping Act Advisory Committee and adopted by the SMGB (DOC, 2004). Under those guideline criteria, liquefaction zones are areas meeting one or more of the following:

1. Areas known to have experienced liquefaction during historical earthquakes

2. All areas of uncompacted artificial fill containing liquefaction-susceptible material that are saturated, nearly saturated, or may be expected to become saturated

3. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable

4. Areas where existing geotechnical data are insufficient

In areas of limited or no geotechnical data, susceptibility zones may be identified by geologic criteria as follows:

a) Areas containing soil deposits of late Holocene age (current river channels and their historic floodplains, marshes and estuaries), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.10 g and the water table is less than 40 feet below the ground surface; or

b) Areas containing soil deposits of Holocene age (less than 11,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.20 g and the historical high water table is less than or equal to 30 feet below the ground surface; or

c) Areas containing soil deposits of latest Pleistocene age (11,000 to 15,000 years), where the M7.5-weighted peak acceleration that has a 10 percent probability of being exceeded in 50 years is greater than or equal to 0.30 g and the historical high water table is less than or equal to 20 feet below the ground surface.

Application of SMGB criteria to liquefaction zoning in the Rosamond Quadrangle is summarized below.

Areas of Past Liquefaction

Documentation of historical liquefaction or paleoseismic liquefaction in the Los Angeles County part of the Rosamond Quadrangle was not found during this study.

Artificial Fills

In the evaluated part of the Rosamond Quadrangle, most artificial fill areas large enough to show at the scale of mapping consist of engineered fill for elevated segments of freeways and overpasses. Since these fills are considered to be properly engineered, zoning for liquefaction in such areas depends on soil conditions in underlying strata. Non-engineered fills are commonly loose and uncompacted and the material varies in size and type.

Areas with Sufficient Existing Geotechnical Data

Combining limited geotechnical information available in the Rosamond Quadrangle with detailed geologic mapping and published water-well data generally provided an adequate basis for evaluating regional liquefaction potential in the area evaluated. The log descriptions and liquefaction analysis indicate that young Quaternary sedimentary layers in the Los Angeles County part of the quadrangle include loose, sandy and silty material that could liquefy where saturated within 40 feet of the surface as illustrated on Plate 1.2. Such conditions occur in an area along the eastern margin of the quadrangle where regional ground-water depths have recently been less than 40 feet, the 1500- to 3000-foot wide wash area occupied by Amargosa Creek, and the large sewage treatment facility situated at State Route 14 and Avenue D. These areas are designated zones of required investigation on the Seismic Hazard Zone Map of the Rosamond Quadrangle.

Areas with Insufficient Existing Geotechnical Data

SMGB Criterion Item 4 (see above) was applied in the undeveloped desert areas of the Rosamond Quadrangle that lacked geotechnical data.

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Thanks go to staff at the California Department, of Transportation, Sacramento District Laboratory; Dan Schneidereit, Bruce Hick, and staff at Earth Systems; Gary Gilbreath, Robert Pierotti, and Timothy Ross at California Department of Water Resources; Charles T. Nestle and Robert Thomas at Los Angeles County Department of Public Works; and Steve Phillips, Devin Galloway, and Peter Martin of the U.S. Geological Survey. Additionally, the author acknowledges CGS staff Terilee McGuire, Lee Wallinder and Bob Moskovitz for providing extraordinary GIS support; Barbara Wanish for preparing the final liquefaction hazard zone maps and graphic displays; Al Barrows for text contributions and editorial support; and student assistants Ben Wright, Ian Penny, Osama Altashi, and Andrea Ignacio, for data entry and digitizing support.

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SECTION 2
EARTHQUAKE-INDUCED LANDSLIDE EVALUATION REPORT

NO LANDSLIDE HAZARDS ZONED

Within the evaluated part of the Rosamond Quadrangle, no areas have been designated as "zones of required investigation for earthquake-induced landslides." However, the potential for landslides may exist locally, particularly along stream banks, margins of drainage channels, and similar settings where steep banks or slopes occur. Such occurrences are of limited lateral extent or are too small and discontinuous to be depicted at 1:24,000 scale (the scale of Seismic Hazard Zone Maps). Within the liquefaction zones, some geologic settings may be susceptible to lateral-spreading (a condition wherein low-angle landsliding is associated with liquefaction). Also, landslide hazards can be created during excavation and grading unless appropriate techniques are used.

SECTION 3
GROUND SHAKING EVALUATION REPORT

Potential Ground Shaking in the Rosamond 7.5-Minute Quadrangle, Los Angeles County, California

By

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California Geological Survey
***Formerly with CGS, now with U.S. Geological Survey**

PURPOSE

The Seismic Hazards Mapping Act (the Act) of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) [now called California Geological Survey (CGS)] to delineate Seismic Hazard Zones. The purpose of the Act is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the Seismic Hazard Zone Maps in their land-use planning and permitting processes. The Act requires that site-specific geotechnical investigations be performed prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board (DOC, 1997). The text of this report is on the Internet at http://gmw.consrv.ca.gov/shmp/webdocs/sp117.pdf

This section of the evaluation report summarizes the ground motions used to evaluate liquefaction and earthquake-induced landslide potential for zoning purposes. Included are ground motion and related maps, a brief overview on how these maps were prepared, precautionary notes concerning their use, and related references. The maps provided herein are presented at a scale of approximately 1:150,000 (scale bar provided on maps), and show the full 7.5-minute quadrangle and portions of the adjacent eight quadrangles. They can be used to assist in the specification of earthquake loading conditions ***for the analysis of ground failure*** according to the "Simple Prescribed Parameter Value" method (SPPV) described in the site investigation guidelines (DOC, 1997). Alternatively, they can be used as a basis for comparing levels of ground motion determined by other methods with the statewide standard.

This section and Sections 1 and 2 (addressing liquefaction and earthquake-induced landslide hazards) constitute a report series that summarizes development of seismic hazard zone maps in the state. Additional information on seismic hazard zone mapping in California can be accessed on the California Geological Survey's Internet page: http://www.consrv.ca.gov/CGS/index.htm

EARTHQUAKE HAZARD MODEL

The estimated ground shaking is derived from the statewide probabilistic seismic hazard evaluation released cooperatively by the California Department of Conservation, Division of Mines and Geology [California Geological Survey], and the U.S. Geological Survey (Petersen and others, 1996). That report documents an extensive 3-year effort to obtain consensus within the scientific community regarding fault parameters that characterize the seismic hazard in California. Fault sources included in the model were evaluated for long-term slip rate, maximum earthquake magnitude, and rupture geometry. These fault parameters, along with historical seismicity, were used to estimate return times of moderate to large earthquakes that contribute to the hazard.

The ground shaking levels are estimated for each of the sources included in the seismic source model using attenuation relations that relate earthquake shaking with magnitude, distance from the earthquake, and type of fault rupture (strike-slip, reverse, normal, or subduction). The published hazard evaluation of Petersen and others (1996) only considers uniform firm-rock site conditions. In this report, however, we extend the hazard analysis to include the hazard of exceeding peak horizontal ground acceleration (PGA) at 10 percent probability of exceedance in 50 years on spatially uniform conditions of rock, soft rock, and alluvium. These soil and rock conditions approximately correspond to site categories defined in Chapter 16 of the Uniform Building Code (ICBO, 1997), which are commonly found in California. We use the attenuation relations of Boore and others (1997), Campbell (1997), Sadigh and others (1997), and Youngs and others (1997) to calculate the ground motions.

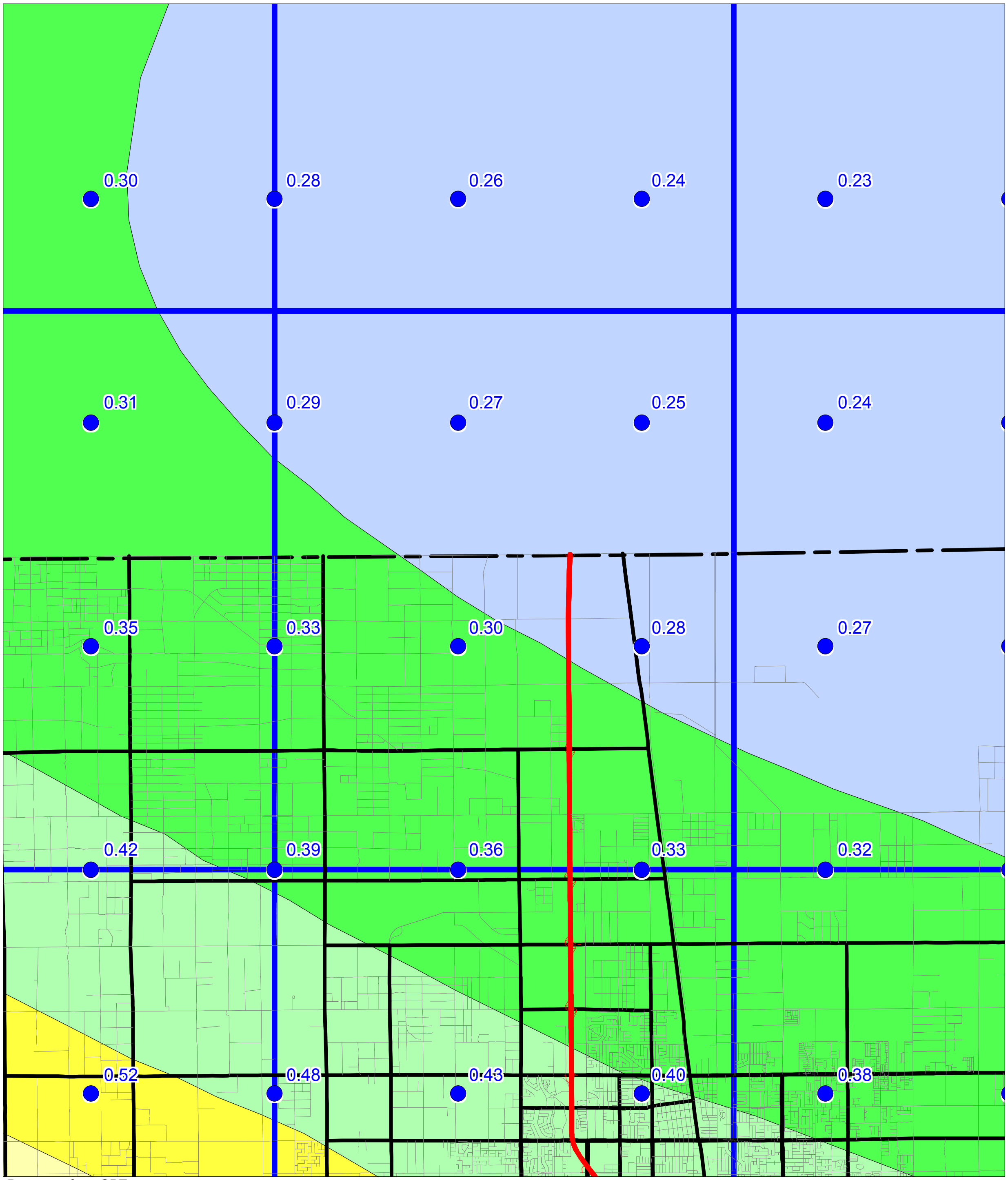
The seismic hazard maps for ground shaking are produced by calculating the hazard at sites separated by about 5 km. Figures 3.1 through 3.3 show the hazard for PGA at 10 percent probability of exceedance in 50 years assuming the entire map area is firm rock, soft rock, or alluvial site conditions respectively. The sites where the hazard is calculated are represented as dots and ground motion contours as shaded regions. The quadrangle of interest is outlined by bold lines and centered on the map. Portions of the eight

ROSAMOND 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

FIRM ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

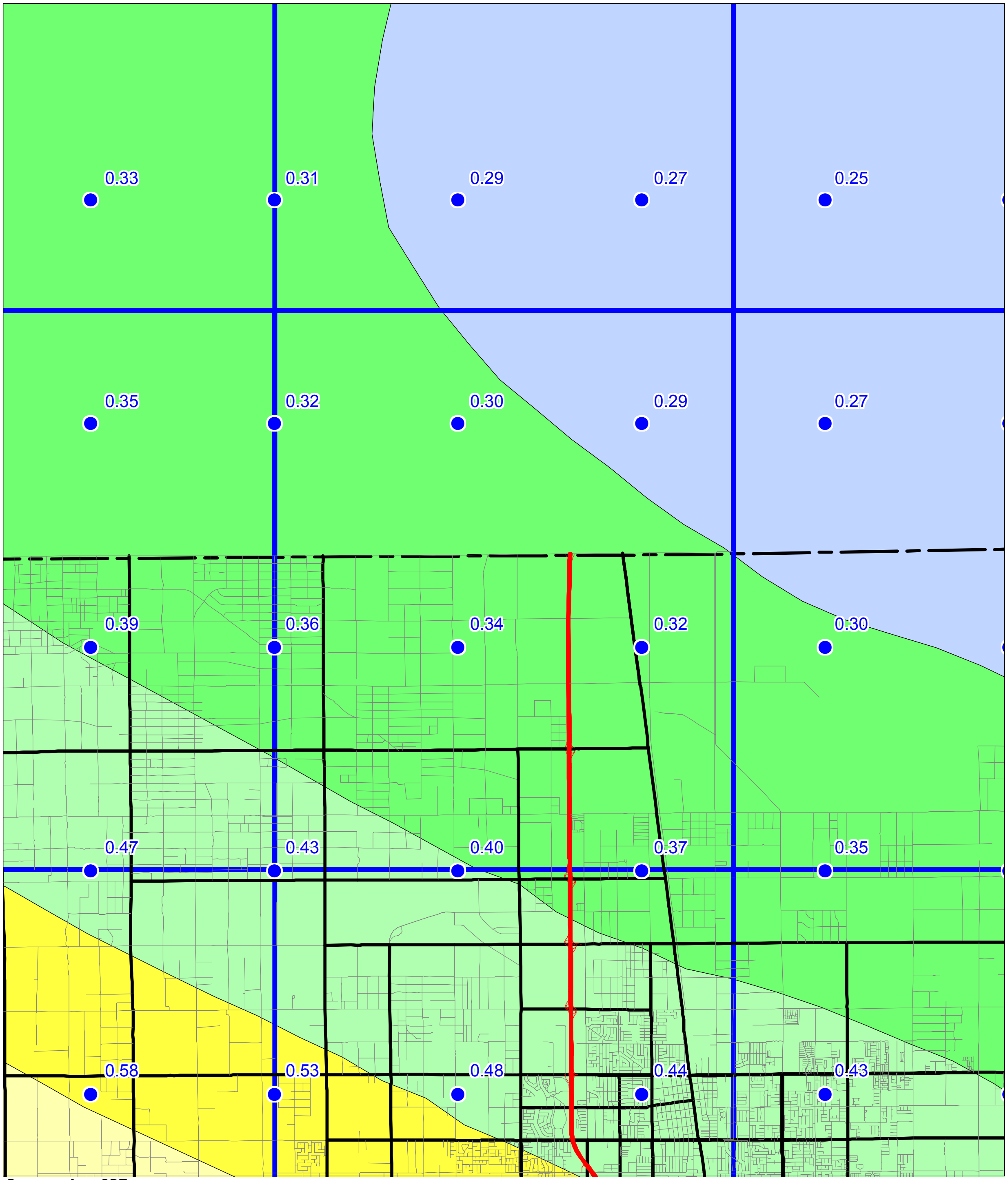
Figure 3.1

ROSAMOND 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

SOFT ROCK CONDITIONS



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

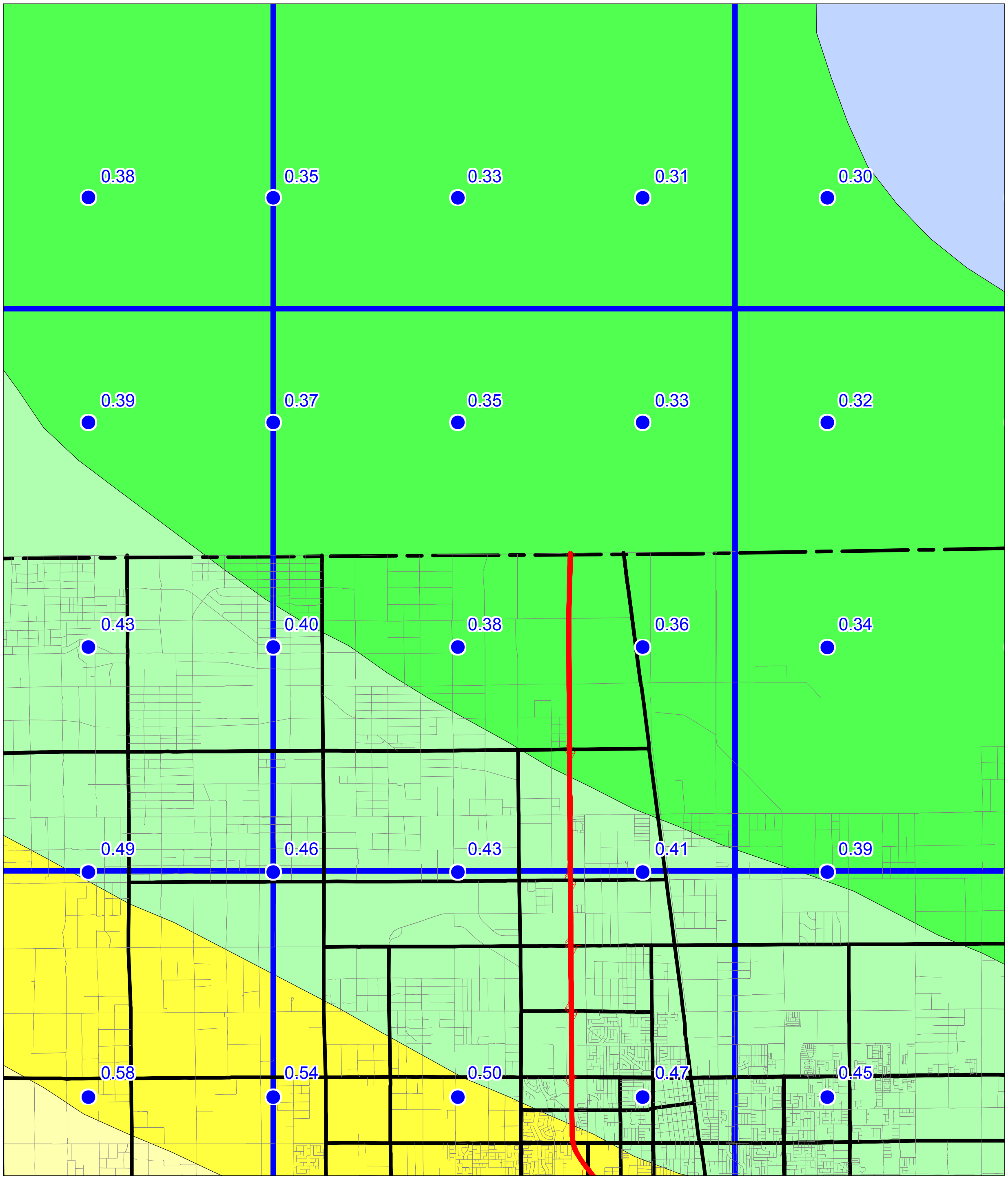
Figure 3.2

ROSAMOND 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION (g)

1998

ALLUVIUM CONDITIONS



Base map from GDT

0 1.5 3

Miles

Department of Conservation
California Geological Survey

Figure 3.3

adjacent quadrangles are also shown so that the trends in the ground motion may be more apparent. We recommend estimating ground motion values by selecting the map that matches the actual site conditions, and interpolating from the calculated values of PGA rather than the contours, since the points are more accurate.

APPLICATIONS FOR LIQUEFACTION AND LANDSLIDE HAZARD ASSESSMENTS

Deaggregation of the seismic hazard identifies the contribution of each of the earthquakes (various magnitudes and distances) in the model to the ground motion hazard for a particular exposure period (see Cramer and Petersen, 1996). The map in Figure 3.4 identifies the magnitude and the distance (value in parentheses) of the earthquake that contributes most to the hazard at 10 percent probability of exceedance in 50 years on alluvial site conditions (*predominant earthquake*). This information gives a rationale for selecting a seismic record or ground motion level in evaluating ground failure. However, it is important to keep in mind that more than one earthquake may contribute significantly to the hazard at a site, and those events can have markedly different magnitudes and distances. For liquefaction hazard the predominant earthquake magnitude from Figure 3.4 and PGA from Figure 3.3 (alluvium conditions) can be used with the Youd and Idriss (1997) approach to estimate cyclic stress ratio demand. For landslide hazard the predominant earthquake magnitude and distance can be used to select a seismic record that is consistent with the hazard for calculating the Newmark displacement (Wilson and Keefer, 1983). When selecting the predominant earthquake magnitude and distance, it is advisable to consider the range of values in the vicinity of the site and perform the ground failure analysis accordingly. This would yield a range in ground failure hazard from which recommendations appropriate to the specific project can be made. Grid values for predominant earthquake magnitude and distance should **not** be interpolated at the site location, because these parameters are not continuous functions.

A preferred method of using the probabilistic seismic hazard model and the "simplified Seed-Idriss method" of assessing liquefaction hazard is to apply magnitude scaling probabilistically while calculating peak ground acceleration for alluvium. The result is a "magnitude-weighted" ground motion (liquefaction opportunity) map that can be used directly in the calculation of the cyclic stress ratio threshold for liquefaction and for estimating the factor of safety against liquefaction (Youd and Idriss, 1997). This can provide a better estimate of liquefaction hazard than use of predominate magnitude described above, because all magnitudes contributing to the estimate are used to weight the probabilistic calculation of peak ground acceleration (Real and others, 2000). Thus, large distant earthquakes that occur less frequently but contribute *more* to the liquefaction hazard are appropriately accounted for.

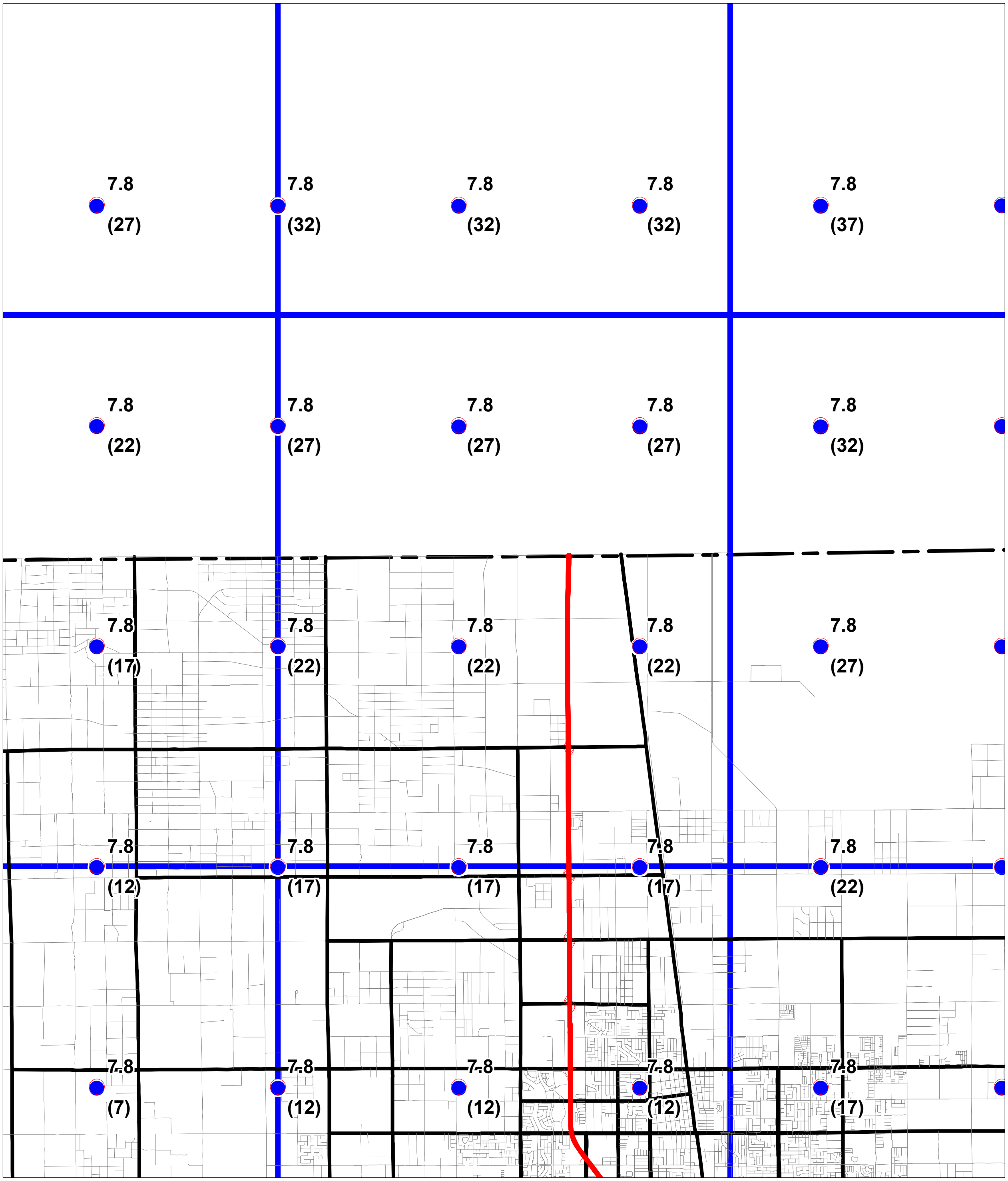
Figure 3.5 shows the magnitude-weighted alluvial PGA based on Idriss' weighting function (Youd and Idriss, 1997). It is important to note that the values obtained from this map are pseudo-accelerations and should be used in the formula for factor of safety without any magnitude-scaling (a factor of 1) applied.

ROSAMOND 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS PEAK GROUND ACCELERATION

1998

PREDOMINANT EARTHQUAKE
Magnitude (Mw)
(Distance (km))



Base map from GDT

0 1.5 3
Miles

Department of Conservation
California Geological Survey

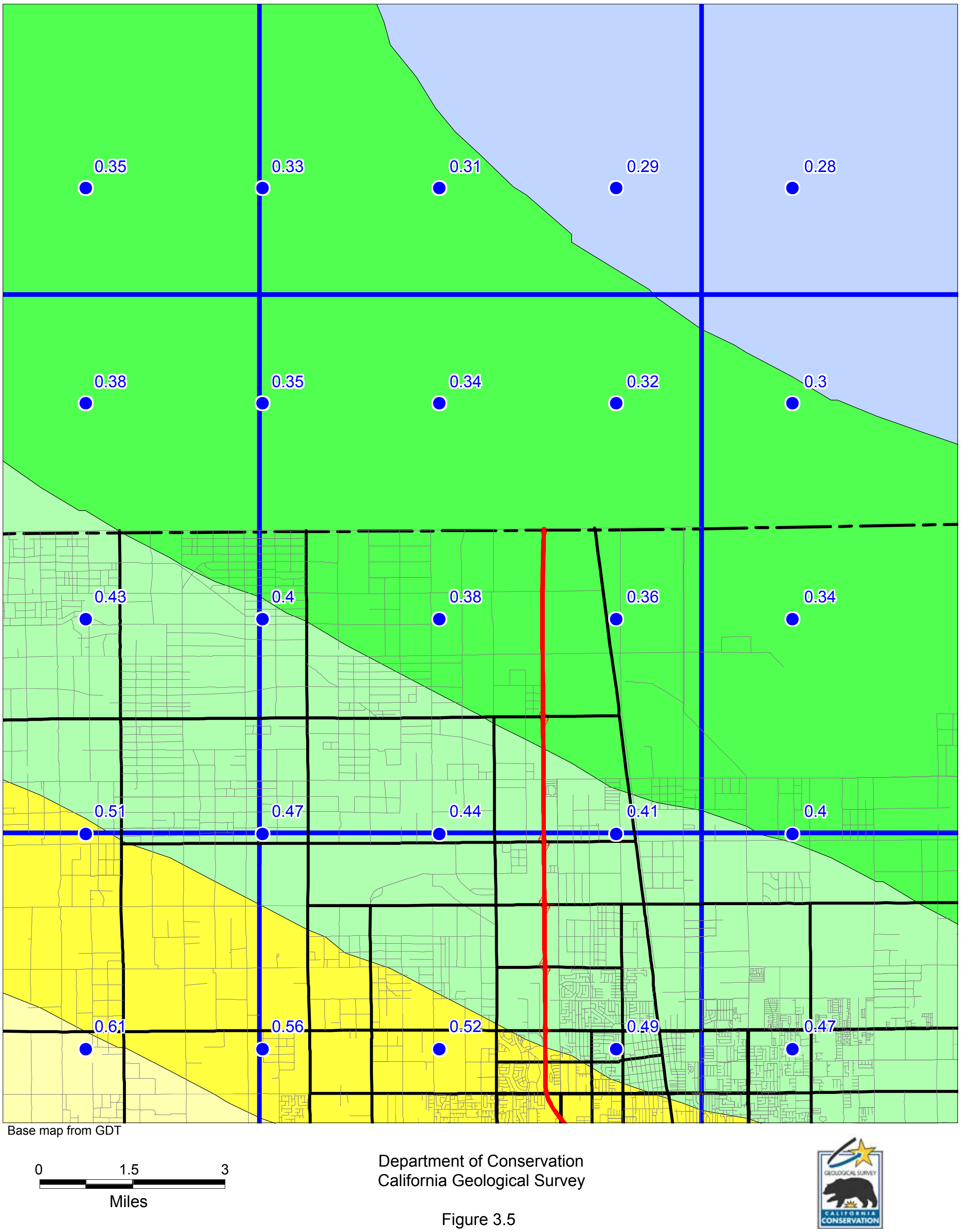
Figure 3.4

ROSAMOND 7.5 MINUTE QUADRANGLE AND PORTIONS OF ADJACENT QUADRANGLES

10% EXCEEDANCE IN 50 YEARS MAGNITUDE-WEIGHTED PSEUDO-PEAK ACCELERATION (g) FOR ALLUVIUM

1998

LIQUEFACTION OPPORTUNITY



Department of Conservation
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Figure 3.5

USE AND LIMITATIONS

The statewide map of seismic hazard has been developed using regional information and is ***not appropriate for site specific structural design applications***. Use of the ground motion maps prepared at larger scale is limited to estimating earthquake loading conditions for preliminary assessment of ground failure at a specific location. We recommend consideration of site-specific analyses before deciding on the sole use of these maps for several reasons.

1. The seismogenic sources used to generate the peak ground accelerations were digitized from the 1:750,000-scale fault activity map of Jennings (1994). Uncertainties in fault location are estimated to be about 1 to 2 kilometers (Petersen and others, 1996). Therefore, differences in the location of calculated hazard values may also differ by a similar amount. At a specific location, however, the log-linear attenuation of ground motion with distance renders hazard estimates less sensitive to uncertainties in source location.

2. The hazard was calculated on a grid at sites separated by about 5 km (0.05 degrees). Therefore, the calculated hazard may be located a couple kilometers away from the site. We have provided shaded contours on the maps to indicate regional trends of the hazard model. However, the contours only show regional trends that may not be apparent from points on a single map. Differences of up to 2 km have been observed between contours and individual ground acceleration values. *We recommend that the user interpolate PGA between the grid point values rather than simply using the shaded contours*.

3. Uncertainties in the hazard values have been estimated to be about +/- 50 percent of the ground motion value at two standard deviations (Cramer and others, 1996).

4. Not all active faults in California are included in this model. For example, faults that do not have documented slip rates are not included in the source model. Scientific research may identify active faults that have not been previously recognized. Therefore, future versions of the hazard model may include other faults and omit faults that are currently considered.

5. A map of the predominant earthquake magnitude and distance is provided from the deaggregation of the probabilistic seismic hazard model. However, it is important to recognize that a site may have more than one earthquake that contributes significantly to the hazard. Therefore, in some cases earthquakes other than the predominant earthquake should also be considered.

Because of its simplicity, it is likely that the SPPV method (DOC, 1997) will be widely used to estimate earthquake shaking loading conditions for the evaluation of ground failure hazards. It should be kept in mind that ground motions at a given distance from an earthquake will vary depending on site-specific characteristics such as geology, soil properties, and topography, which may not have been adequately accounted for in the regional hazard analysis. Although this variance is represented to some degree by the recorded ground motions that form the basis of the hazard model used to produce Figures 3.1, 3.2, and 3.3, extreme deviations can occur. More sophisticated methods that take into account other factors that may be present at the site (site amplification, basin effects, near source effects, etc.) should be employed as warranted. The decision to use the SPPV method with ground motions derived from Figures 3.1, 3.2, or 3.3 should be based on careful consideration of the above limitations, the geotechnical and seismological aspects of the project setting, and the "importance" or sensitivity of the proposed building with regard to occupant safety.

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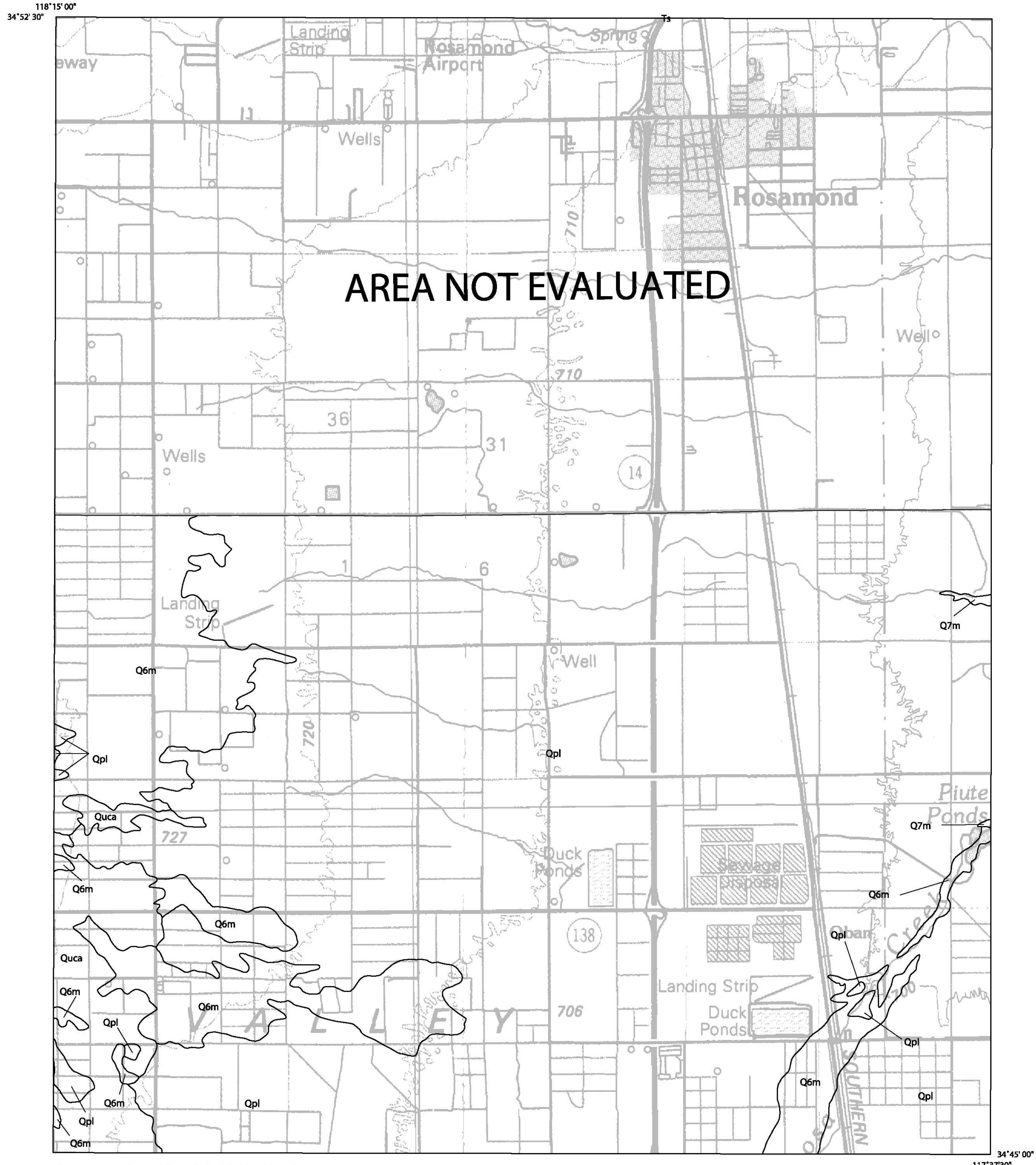
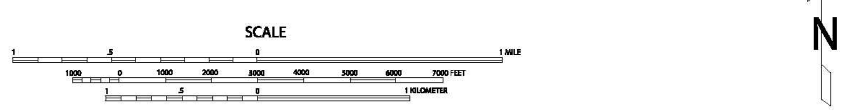


Base map enlarged from U.S.G.S. 30 x 60-minute series

ROSAMOND QUADRANGLE



See "Bedrock and Surficial Geology" in Section 1 of report for descriptions of units.

Plate 1.1 Quaternary Geologic Map of the Rosamond 7.5-Minute Quadrangle, California. Geology modified from Ponti and others (1981).

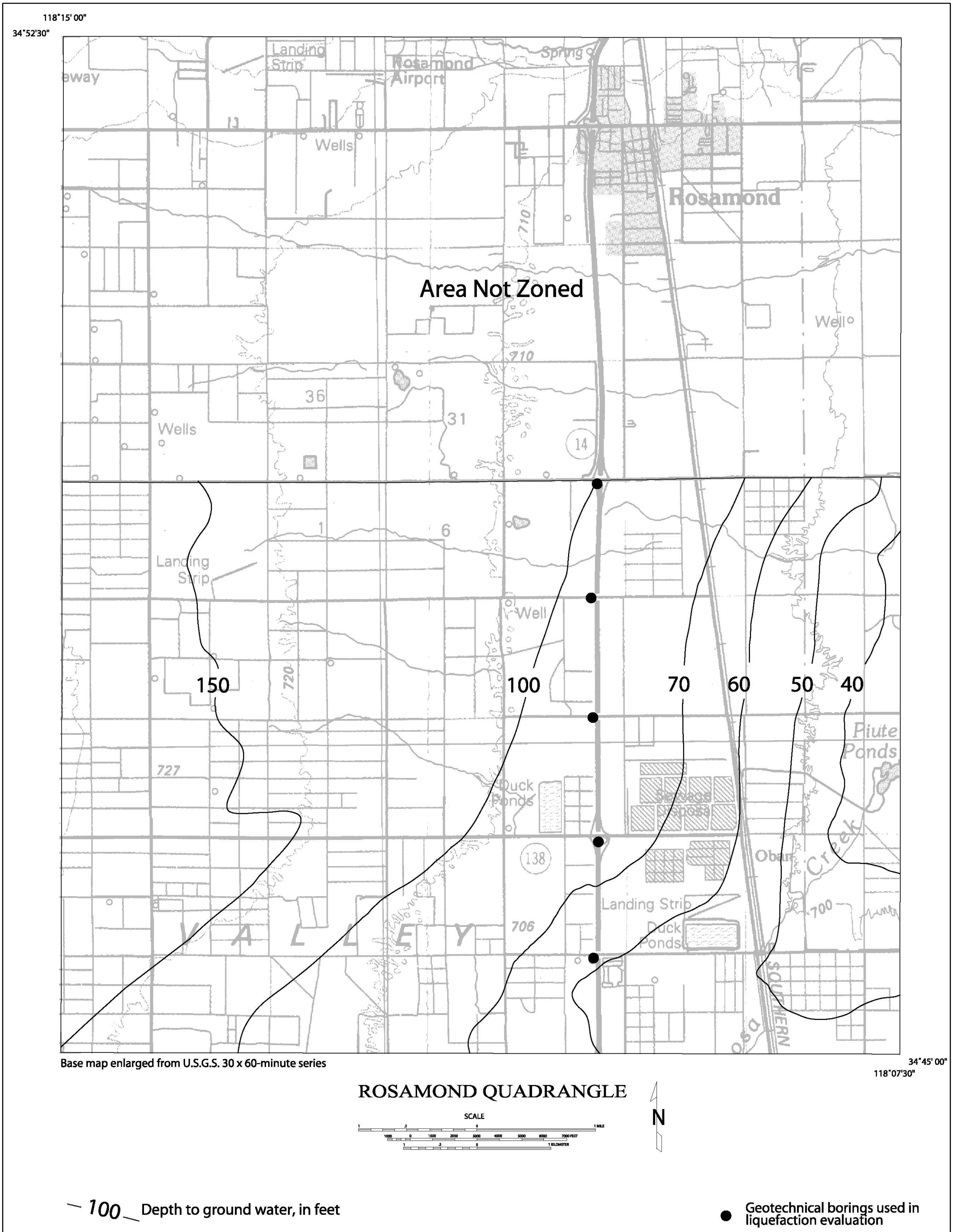


Plate 1.2 Depth to ground water, and locations of boreholes used in this study, Rosamond 7.5-Minute Quadrangle, California. Regional ground-water levels based on Carlson and Phillips (1998).